ESQD ARCS FOR MARITIME PREPOSITIONING SHIPS

by

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ABSTRACT

The United States Marine Corps operates 13 Maritime Prepositioning Ships (MPS). Each of these ships can contain up to 1.3 million pounds (Net Explosive Weight (NEW)) of all types of Marine Corps munitions. These ships are periodically returned to Blount Island in the St. Johns River, Jacksonville, Florida, for refurbishment of their equipment. At an NEW of 1.3 million pounds, the standard value of the inhabited building distance encroaches upon several private dwellings.

In order to address this problem, the U.S. Navy has conducted a large scale test (NEW of over 500,000 pounds) and series of analyses to determine a more realistic estimate of the inhabited building distance. This report presents the background and history of the the problem, describes the set-up and conduct of the event, and summarize the data collected and its interpretation. One outcome of this program was the reduction of both the inhabited building distance and the public traffic route distances by approximately 18%. These ranges were driven by airblast and not by fragmentation.

INTRODUCTION

The United States Marine Corps (USMC) currently operates thirteen (13) maritime prepositioning ships (MPS). The concept of these ships is that each squadron contains all the stores, ammunition, and equipment needed by a Marine Expeditionary Brigade for 30 days of combat operations. Because of the ammunition carried aboard these ships, an explosive safety quantity-distance (ESQD) arcs must be in place whenever these ships come into port.

The thirteen ships are drawn from three separate ship classes; however, the Net Explosive Weight (NEW) associated with each ship is quite similar, ranging from 1.0 to 1.3 million pounds. All three classes of ships are breakbulk, container ships (note: The containers utilized are International Standards Organization (ISO) vans). In the Maersk class, the energetic materials are stored in Holds 2, 3, and 4. Hold 4 is separated from Hold 3 by approximately 50 feet of general cargo. In the Waterman class, the energetic material is stored in Holds 1, 2, and 3, while in the Amsea class it is stored in Holds 1 and 2.

All of the energetic material is stored in either standard ISO containers whose external dimensions are 19.875' L x 8.0' W x 8.0' H or half-height containers whose external dimensions are 19.875' L x 8.0' W x 4.17' H. The standard ISO container has walls and roof whose minimum thickness is 4 mm of mild steel. The half-height container has walls of 4 mm steel, but a canvas top.

Report Documentation Page	*Form Approved* *OMB No. 0704-0188*

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **AUG 1992**	2. REPORT TYPE	3. DATES COVERED **00-00-1992 to 00-00-1992**
4. TITLE AND SUBTITLE **ESQD Arcs for Maritime Prepositioning Ships**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center,Indian Head Division,10901 New Hampshire Avenue,Silver Spring,MD,20903-5640**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADA261116, Volume IV. Minutes of the Twenty-Fifth Explosives Safety Seminar Held in Anaheim, CA on 18-20 August 1992.

14. ABSTRACT
see report

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**23**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Every two years, under normal conditions,these ships are returned to Blount Island (in the St. Johns River at Jacksonville, Florida) as part of the maintenance cycle for the ordnance and equipment located on board. Here the equipment is off-loaded and the ordnance is shipped by rail to the Naval Weapons Station, Charleston, South Carolina, for inspection and refurbishing (as needed). The material is then shipped back to Blount Island and reloaded aboard the ships. The current explosive safety arc for this operation is based on a NEW of 1,300,000 pounds--the projected maximum amount aboard any of the MPS ships.

STATEMENT OF THE PROBLEM

The applicable ESQD arcs are defined in Navy publication OP-5, Volume 1.[1] The arcs for two conditions are of interest--Inhabited Building Distance (IBD) and Public Traffic Route (PTR). Table 1 gives the standard values for three NEW's. After examination of maps of the area, it was determined that the problem area was the IBD for the 1,300,000 pound NEW--an ESQD range of 5,460 feet. A hazard arc of this size would encroach on several private dwellings located across the St. Johns River.

POTENTIAL SOLUTIONS

Five potential solutions to the encroachment problem at Blount Island were discussed. These were: (1) Purchase the civilian properties involved, (2) Apply to the Chief of Naval Operations for a waiver of the rules, (3) Reduce the NEW aboard each ship, (4) Reduce the Maximum Credible Event (MCE) for an accident aboard ship, and (5) Conduct one (or more) large scale tests to measure the TNT equivalence of the ship and make a direct estimate of the ESQD ranges. Each of these will be discussed in more detail in the following sections.

Purchase Land Involved. This option was felt to be too expensive and could set an unwanted precedent.

Apply for Waiver. It was felt that if this option were pursued, then the owners of the encroached land could bring a law suit for reduction of their property values. Further, a temporary restraining order causing the cessation of all explosive operations at Blount Island would probably be issued until the case could be adjudicated.

Reduce NEW. This option was deemed operationally unacceptable. However, based upon lessons learned from the war in Southwest Asia, ammunition requirements have been reconfigured. The required 30-day fighting capability still exists as advertised, but at an NEW of 1.3 million pounds..

Reduce MCE. Less sensitive ordnance/ammunition items already carried aboard the ships would be used as buffer materials between stacks of more sensitive items. This effort has been pursued/implemented by the USMC and will be discussed below. However, because of the number of tests and analyses that would be required by the Department of Defense Explosives Safety Board (DDESB) to prove an MCE reduction, formal recognition of its use was not pursued.

Conduct Large Scale Test(s). After discussions with the DDESB Secretariat, a single large-scale test was devised--a test involving at least 500,000 pounds NEW of ordnance. The results of this test form the basis for the proposed and accepted reductions of the ESQD arcs for the thirteen MPS ships.

MAXIMUM CREDIBLE EVENT REDUCTION

There are ongoing programs in both the Army and the Air Force on the use of less sensitive energetic items as buffers or shields between stacks or containers of munitions. Two of these programs are called "Quickload" in the Army and "Buffered Storage" in the Air Force.

Quickload. The one aspect of the Quickload program which is of use here is the concept of using propellant charges as shielding material. The Army has conducted extensive tests using 5-inch and 8-inch propellant charges between stacks of 5 and 8 inch projectiles filled with Composition B, TNT, and with sub-munitions. They have had success with the TNT-loaded and the 5" Composition B loaded projectiles. However, even with 19 rows of propellant charges intervening, the 8-inch Composition B rounds and the ICM (Improved Conventional Munition) rounds still sympathetically detonate.

It should be noted that these results were obtained from tests which were conducted with, essentially, no confinement--i.e., either in the open or the minimum confinement provided by the individual stacks of munitions.

Buffered Storage. The Air Force Buffered Storage concept utilizes less sensitive (or inert) items as buffer material between stacks of MK 80 series bombs. Through a combination of separation distance and buffer density, the concept has been demonstrated by preventing sympathetic detonation between 60,000 pound stacks of tritonal-loaded bombs. From the standpoint of application to this problem, one of the most interesting aspects of the Air Force tests is the successful use of cluster bombs (both MK 20 and MK 58) as buffer material. In operational use, however, the Air Force has decided not to use any Class 1.1 material as a buffer. This does not mean that it doesn't work--merely that they have the option of having other suitable materials available to use as buffers. Also, the concept of using Class 1 ammunition between stacks of Class 1 ammunition would require extensive test and analysis by the DDESB Secretariat.

The concept, as proposed for the MPS ships, is not to totally eliminate sympathetic detonation; rather, it is to use prudent stowage techniques, utilizing certain containers as buffer material, to isolate one hold from another and thus delay the times of reaction of the additional holds and reduce the total event.

The suitable barrier or provision of adequate separation required can be supplied by double rows of containers--one along the aft wall of the forward hold and another along the forward wall of the next adjacent hold. These buffer containers must be placed on every deck of both holds. The containers would be filled with materials which are normally stored aboard the ship and which have been demonstrated to act as a shield or buffer to prevent

detonation.

Buffer Materials. If the concept is to be implemented with a double row of buffers (one on each side of the wall separating the two holds) approximately 120 containers will be required--60 along each side of the wall (note: this number will vary somewhat between the various classes of ships).

Let us make the following definitions of material which may be used either separately or in combination as buffer material:

(1) Class B propellant charges
(2) Cluster bombs
(3) Illuminating projectiles or smoke producing warheads
(4) Non-mass-detonating munitions
(5) Special fireworks and/or small arms ammunition
(6) Time fuze/detonating cord.

The selection for the first two of these has been discussed above and is based on the Army and Air Force test results. The remaining categories were chosen because they would be the least likely to propagate a detonation to subsequent containers.

If the hazardous cargo manifest of a typical MPS ship is examined, it can be shown that there are sufficient containers to act as buffer material. Any arrangement of containers, selected from the types of material presented in the list above, which achieves the goal of a double buffer layer would be acceptable.

DISCUSSION

The containers and the material which are located therein will act as fragment suppressors, greatly reducing the number and velocity of fragments reaching the potential acceptor munitions.

Previous tests[2,3] conducted during the 1970's addressed the propagation of detonation between stacks of containers. These tests, in some cases, added the extreme confinement which would be present during shipboard storage below the water line. In the final test of the series described in Reference 5, 33 MILVANS were loaded side-by-side, stacked three high in a 21-foot deep hole. The donor was 2 MILVANS containing 144 MK 82 bombs. The acceptor was 16 MILVANS containing 1,152 MK 82 bombs. The buffer consisted of 15 MILVANS of palletized 90 mm cartridges (a total of 7200). The buffer material was described as Shell, fixed, HE, M71 (DODIC C267). The donor had a NEW of 27,468 pounds; the acceptor 221,184. The buffer contained 15,480 pounds of explosive and 52,635 pounds of propellant. The result was a high order detonation. One MK 82 bomb and five 90 mm projectiles were recovered.

All of the smaller tests leading up to this proof of concept test had indicated success. The major differences between the previous tests and the final test were twofold: (1) the size of the test (scale-up of smaller results), and (2) the effects of confinement.

The previous test results should have a bearing on the current effort, but the negative

results should not cause disheartenment. The situations are not the same. The buffer material has been tested and proven to work up to the 60,000 pound NEW donor size. The 90 mm cartridges used previously will not be used--only propellant charges or charges without warheads (the cluster bombs proposed have been verified by tests with heavy confinement).

These concepts were discussed on an informal basis with the DDESB Secretariat. They (the DDESB Secretariat) indicated that their current philosophy is to require testing for all new or drastically-revised stowage concepts. As was discussed above, all of the concepts upon which these recommendations are based have been tested separately; however, the combination (or system of concepts) have not. As the MILVAN tests indicated, there may be synergistic effects which we have not addressed or recognized. The DDESB also has very strong concerns about Class/Division (C/D) 1.1 materials as potential buffers between other C/D 1.1 materials.

Because of this and the number of tests and analyses which would be required before the DDESB Secretariat would approve the process, it was decided not to seek formal approval or recognition for the utilization of this concept. However, the USMC would, on their own, implement as much as possible of this loading concept on all future ship loadouts.

MPS TEST CONCEPT AND ARRANGEMENT

After many discussions with the DDESB, a single large-scale test was agreed upon. This test was to have the following attributes:

(a) Must include approximately 1/3 of all ordnance carried aboard ship. Nominal NEW of test should be 500,000 pounds.
(b) All material should be stored in ISO containers as it would be aboard ship.
(c) Material should be arranged in a similar manner as aboard ship. It should be configured to represent two levels of one vertical hold.
(d) Numbers and types of items to be included should be determined from manifest of typical MPS ship.
(e) Test should include confinement effects produced by material stored below water-line of ship.
(f) C/D 1.3 materials should be placed in positions of greatest confinement
(g) Test must provide multiple detonation sources.

Since only one test was to be performed, the test must be configured to represent a truly "worst case"; i.e, the test would not, necessarily, represent a viable hazard or threat scenario. Rather, everything should be done to maximize the output of the event.

TEST OBJECTIVES

As planned, the test would have several objectives. These would include:

(1) For a realistic arrangement of ordnance stored in ISO vans, determine the airblast propagation characteristics (pressure-distance and impulse-distance).
(2) At selected locations, determine the dynamic pressure produced by the detonation.
(3) From the measured blast characteristics, determine a TNT equivalence for the event.
(4) Determine the debris density as a function of range from the center of the charge.
(5) From the measured airblast and debris characteristics, determine the ESQD arcs which should be applied to a full scale ship.
(6) Determine the number and NEW of unexploded ordnance produced by the event.
(7) Compare pre-test airblast predictions with the measured results.

TEST PARTICIPANTS

At the start of this effort, several potential test sites were examined. As the size and complexity of the test became clear, it was decided that the test would be conducted at the Naval Weapons Center (NWC) (currently, the Naval Air Warfare Center (NAWC), China Lake, CA). They (NWC) would have the responsibility for final site selection, site preparation, loading and stacking of containers, charge detonation, high speed photography, and preliminary report preparation.

Airblast would be measured by the U.S. Army Waterways Experiment Station, Vicksburg, MS. The airblast measurements would include side-on overpressure at all gauge locations and dynamic pressure at selected locations.

CHARGE ARRANGEMENT

The charge arrangement was patterned after the loadout of the MPS ship PFC DEWAYNE T. WILLIAMS. The loadout for this ship was examined in detail. The contents of every third container of ordnance material were selected for inclusion on this test. These contents were compared with material which was available from the DEMIL (Demilitarization) inventory. Where material was not available, substitutions were made. The basic rules for substitution were that materials of the same hazard class/division should be used. Further these should have the same approximate sensitivity as the items being replaced. For safety reasons, cluster bombs would not be included on the test. Instead, the cluster bombs would be replaced by 155 mm projectiles. It was felt that the projectiles would be more likely to mass detonate than the cluster bombs. Moreover, if detonation did occur, the blast and fragmentation from the projectiles would be more likely to propagate a sympathetic detonation.

The confinement produced by the fact that portions of the holds are below the waterline would be simulated by placing the lower portion of the ordnance below the ground level. As finally configured, the test would consist of 96 ISO vans of ordnance and 38 vans of inert material-- configured to represent two levels of one hold.

Figure 1, provided by NAWC shows a front view drawing of the test configuration. Figure 2 (also provided by NAWC) shows a plan view of each level. A total of 134 ISO vans were used in the test. The total ordnance weight was 2,265,770 pounds with a net explosive weight of 523,790 pounds. The simulated deck plates shown in these figures were made from 1/4-inch steel plates (10' x 40'). The south side of the stack (with a sloping side rather than dirt confinement) represented the lessened confinement present toward the bow of the ship.

The ordnance and containers were pre-staged at the Cactus Flats Ordnance Field Test Site. When the containers were loaded and their contents documented, they were transported to the actual test site. The test site was located at Airport Lake on the Naval Weapons Center North Range. Marine Corps personnel assisted in transporting the loaded containers from Cactus Flats to Airport Lake.

Fourteen containers were selected as donors. These fourteen containers were scattered throughout the charge stack. All of the donor containers were primed and simultaneously detonated. The total NEW of the donor was 103,555 pounds.

The test was detonated on 7 September 1990. The remainder of this report discusses the results of that detonation.

DATA COLLECTION

Data were collected along three five-degree radials extending outward from the ground zero area. Figure 3 is a schematic of the area showing the locations and types of measurements undertaken.

Airblast. Side-on overpressure was measured at five locations along three radial lines. Piezoresistive transducers mounted flush with the ground surface were used to make these measurements. The data were recorded on transient data recorders with analog FM (Frequency Modulation) tape recorders as back up. Reflected pressure was measured on two ISO vans placed at ranges of interest. Near the same location as the vans, side-on overpressure gauges were also located. Dynamic pressure would be inferred from the combination of reflected and side-on pressure.

Debris. The three 5°-sectors shown in Figure 3 were sub-divided into hundred-foot increments for purposes of debris recovery and analysis. The debris survey was accomplished by USMC EOD (Explosive Ordnance Disposal) personnel under the direction of the Naval Surface Warfare Center.

Within each 5° radial, the debris survey was started at a range greater than 4000 feet from ground zero, with the survey proceeding inward toward ground zero. Everything located beyond 4000 feet was consolidated into a single reading. Each 100-foot sector was surveyed independently. The criteria for consideration was that the material had to be larger than 1/2" x 1/2" x 1/2". Calculations had shown that material smaller than this would not be hazardous (i.e., have an impact energy greater than 58 ft-lbs).

TEST RESULTS

AIRBLAST

The airblast results, which are provided by the Waterways Experiment Station, are presented in Table 2.

Least Square Curve Fits. In order to best utilize all of the airblast data, the method of least squares was used to fit curves to the data. These are shown in Figures 4 for peak pressure and Figure 5 for positive impulse. Shown on each graph are the forms of the curve fits. The pressure-distance data was best fit by a quadratic to the logarithms of the data. The impulse-distance data was best fit by a simple power law.

Dynamic Pressure Estimates. As stated above, reflected pressure measurements were made at two locations. The gauges were placed in the center of the side-wall of ISO vans and the gauge/van placed perpendicular to the direction of blastwave propagation. The results are given at the bottom of Table 2.

The purpose of the reflected pressure measurements was to determine if there were unexpected dynamic pressure effects produced either by the size of the charge, its contents, or its configuration. Using the Rankine-Hugoniot relationships and the procedures described in Reference 4, the reflected pressure was estimated from the measured side-on overpressure. This estimate assumes that the blast wave producing the shockwave meets the requirements for a classical blast wave; i.e., that there is no additional component to the dynamic pressure. This comparison between the measured and predicted is shown in Table 3. It is obvious from the small differences in the measured and predicted reflected pressures that the dynamic pressure effects are those predicted for a classical shockwave produced by the detonation of the given NEW.

Kingery Hemispherical Standard. The scaled distances to which airblast quantity-distance criteria refer are directly related to peak overpressure. The relationship is based on the Kingery compilation of surface burst hemispherical TNT data.[5,6], referred to hereafter as the Kingery TNT standard. Figures 6 and 7 show the comparison between the MPS results and the Kingery standard for both peak pressure and positive impulse. Clearly, the data fall well below the Kingery curves for the NEW of the test.

DEBRIS

As indicated in the previous section, debris data were collected along three radial directions. Tables 4, 5, and 6 present the debris data collected during this test. On the South radial, no debris recovery was attempted inside a radius of 1600 feet. The debris density in this area was so high that recovery was not feasible. Along the North radial and a portion of the West Radial (between 1000 and 1600 feet), the ground was extremely soft and sandy. It was felt that some of the fragments may have become buried in this area and would not have been counted. The on-site personnel felt that to be conservative the number of fragments recovered in these areas should be increased by 25%. This would alleviate any problems of undercounting. The data in Tables 4 and 5 were increased by this

amount before the data were plotted or debris densities computed.

Recently accepted standardized procedures[7] for the analysis of debris have been used in this study. These involve the computation of a pseudo-trajectory normal debris density as a function of range. Figure 7 presents the debris density data produced by this test.

UNEXPLODED ORDNANCE

After the debris survey in the five degree sectors was completed, the USMC EOD team swept the entire test area to render it safe. During that sweep, the amount of unreacted ordnance was determined. This is shown in Table 7. By far, the largest amounts, both in quantity and NEW were the 155 mm projectiles. A total of 49,551 pounds of ordnance was recovered. This means that about 9.5% of the total NEW did not react.

DATA ANALYSIS AND INTERPRETATION

TNT Equivalence. One of the objectives of this program was to determine the TNT equivalence (relative to the Kingery Hemispherical TNT Standard) of the event. TNT equivalence can be based on any of the measured airblast parameters. In this effort, TNT equivalences based on peak overpressure and positive impulse will be reported. Graphs of TNT equivalence are shown in Figure 8. As can be seen, the TNT equivalence varies greatly with the pressure level (range). A single value for the equivalence could be extremely misleading.

Prior to the conduct of the test, nominal TNT equivalences were assigned to each item included on the test. The result was an estimated average TNT equivalence for the energetic material of 0.80. The actual average TNT equivalence (compared to the hemispherical standard), as determined from the information in Figure 8, was 0.55 based on peak pressure and 0.57 based on positive impulse. The difference between the 0.80 and the 0.55-0.56 values represent the effects of the casing material, the confinement provided by the structure and the configuration, and differences between hemispherical and nearly cubical charge geometries.

Airblast Hazard Range. The two airblast hazard ranges of interest are the inhabited building distance (IBD) and the public traffic route distance (PTR). Reference 1 states that for charge weights greater than 250,000 pounds, IBD occurs at a pressure level of 0.9 psi. Likewise, PTR occurs at a range of 1.7 psi. The least squares curve given in Figure 4 best represents all of the pressure-distance data. It will be used to determine these ranges. They are 3250 feet for IBD and 1910 for PTR. These ranges, however, only represent the test conditions. They still have to be scaled up to the full scale event. This is accomplished by using Hopkinson or cube root scaling. The full scale numbers would be obtained by multiplying the ranges shown above by the factor (FULL SCALE NEW/523,790)$^{1/3}$. These results are given in Table 8 for a range of full scale NEW's.

Debris Hazard Range. The debris hazard range is defined at that range at which the density of hazardous fragments (those having an impact energy of 58 ft-lbs or greater) reaches 1 per 600 ft^2. These ranges can be obtained from the debris density-distance curves given in Figure 9. Once the debris ranges for the test are obtained, the problem still

remains how to scale them up to the full scale event.

Debris range does not Hopkinson scale. The author has not found an approved debris scaling methodology. He has examined two approaches, both of which seem conservative, and has decided to use the approach which gave the greater ranges. These two approaches are:

(a) The number of debris pieces is directly proportional to the charge weight ratio. This means that the number of debris would be multiplied by 3 (1,500,000/500,000) in a full scale event. The 1 per 600 ft^2 range would then be determined from this new, increased distribution.
(b) The number of debris pieces is proportional to the cube of the charge weight ratio. This means that the number of debris would be multiplied by 27 $(1{,}500{,}000/500{,}000)^3$ in a full scale event. The 1 per 600 ft^2 range would then be determined from this new, increased distribution.

The major portion of the ship's structure was not modeled in this test. This structure would contribute to the debris, increasing the range. The author feels that by choosing the method giving the greatest range, the effects of this added debris are, essentially, included.

The debris ranges are presented in Table 9. Included are the "as built ranges" determined from Figure 9, as well as the results obtained by increasing the number of debris by both a factor of 3 and a factor of 27. The greatest debris range is less than 4000 feet--less than the airblast ranges given above. It should be pointed out, however, that this does not mean that there will be no debris beyond this range; rather, that the debris density falls below the accepted criteria.

RECOMMENDED ESQD RANGES

The ESQD range is the larger of the two ranges determined by airblast and debris. For the MPS ships, the airblast produced drives the ESQD ranges. This program and its experimental results were presented at the 304th formal meeting of the Department of Defense Explosives Safety Board held on November 27-28 1990. At that time, the NEW of the test was thought to be 503,516 pounds, rather than the current figure of 523,790 pounds. For this reason, the ranges recommended to and accepted by the DDESB are slightly different than those given in the preceding section. The following are the recommended ESQD ranges adopted by the DDESB:

(a) Debris Range of 4400 feet
(b) Airblast range of $40.85W^{1/3}$ for IBD and $24.81W^{1/3}$ for PTR, where W is the total NEW in pounds.

These relationships were used to generate Table 10, which currently will apply only to the original thirteen USMC MPS. These newly accepted ranges will greatly alleviate the encroachment problem described above.

ADDITIONAL DISCUSSIONS

Before the proposed ranges were accepted, there were many detailed discussions with the DDESB Secretariat as to the proper interpretation of the airblast results. As a result of the least squares curve fitting process, approximately 50% of the data points will lie above the fitted curve. Because safety decisions will be based on the airblast pressure-distance data and because there is only a limited test data base, the DDESB Secretariat has recommended that some type of safety factor be applied to the data to make it more safety conservative. This is discussed further in Reference 8.

The MPS program did not have to meet this requirement since it was ongoing when this guidance was developed.

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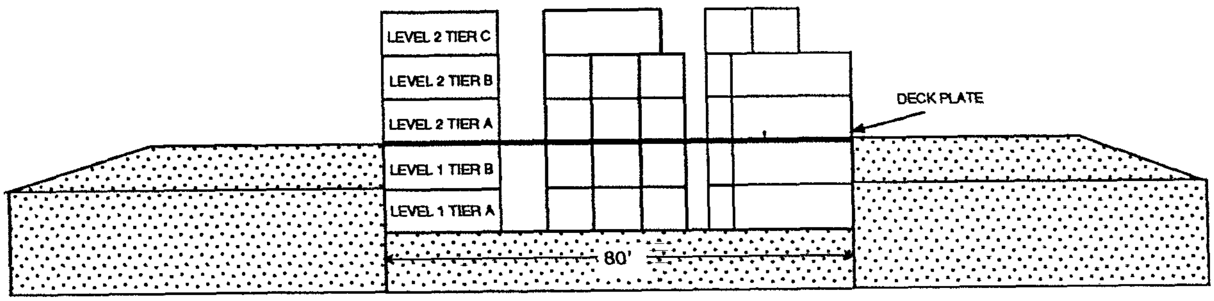

FIGURE 1. FRONT VIEW DRAWING OF THE TEST CONFIGURATION

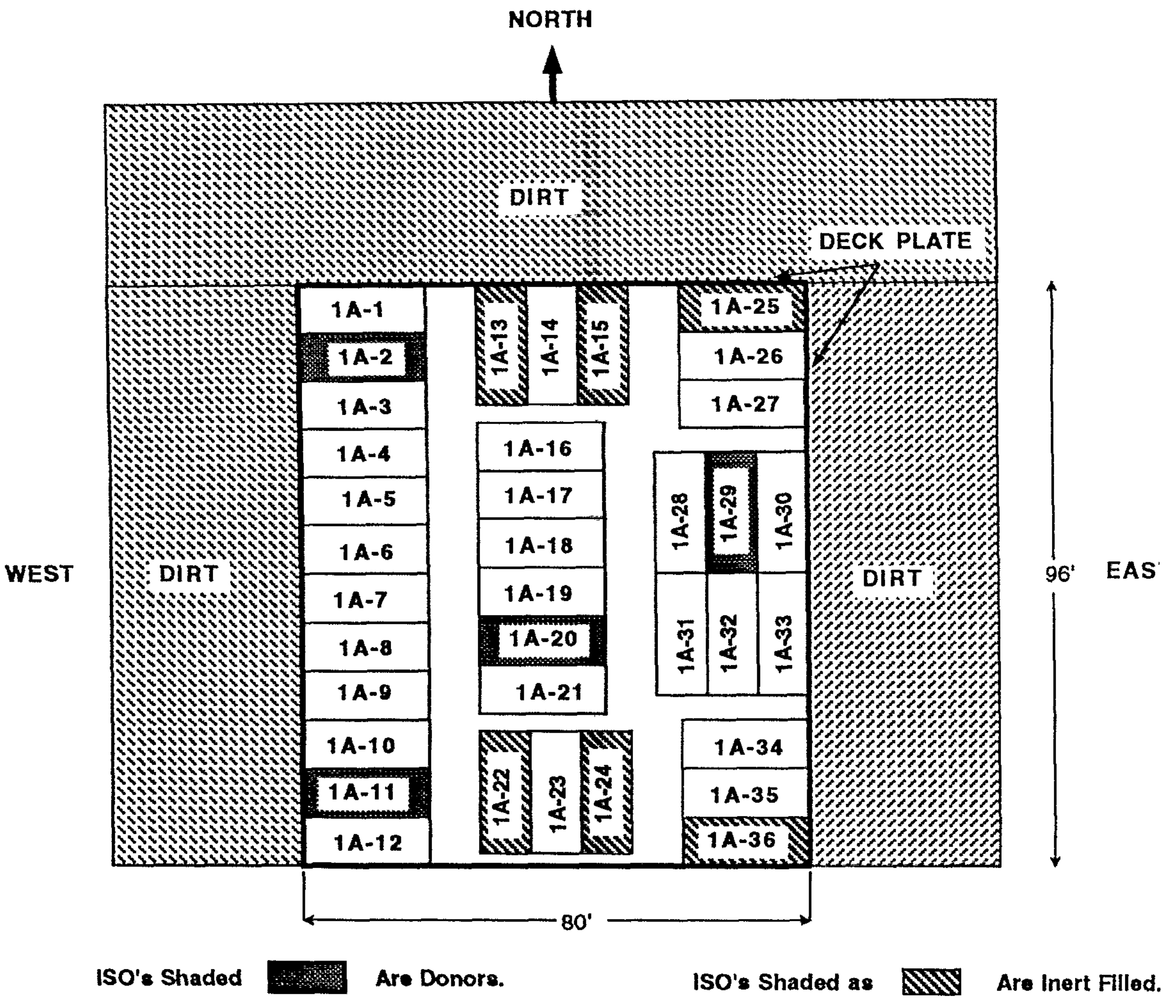

FIGURE 2A. PLAN VIEW OF LEVEL 1, TIER A OF THE TEST CONFIGURATION

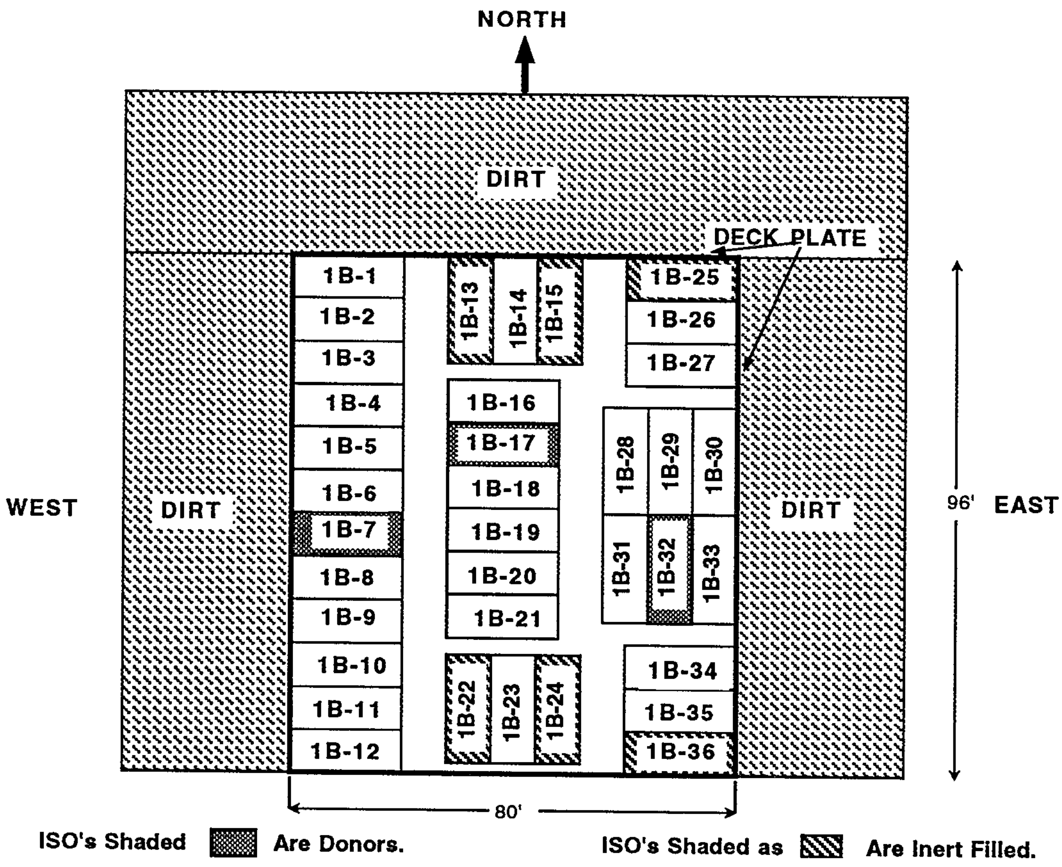

FIGURE 2B. PLAN VIEW OF LEVEL 1, TIER B OF THE TEST CONFIGURATION

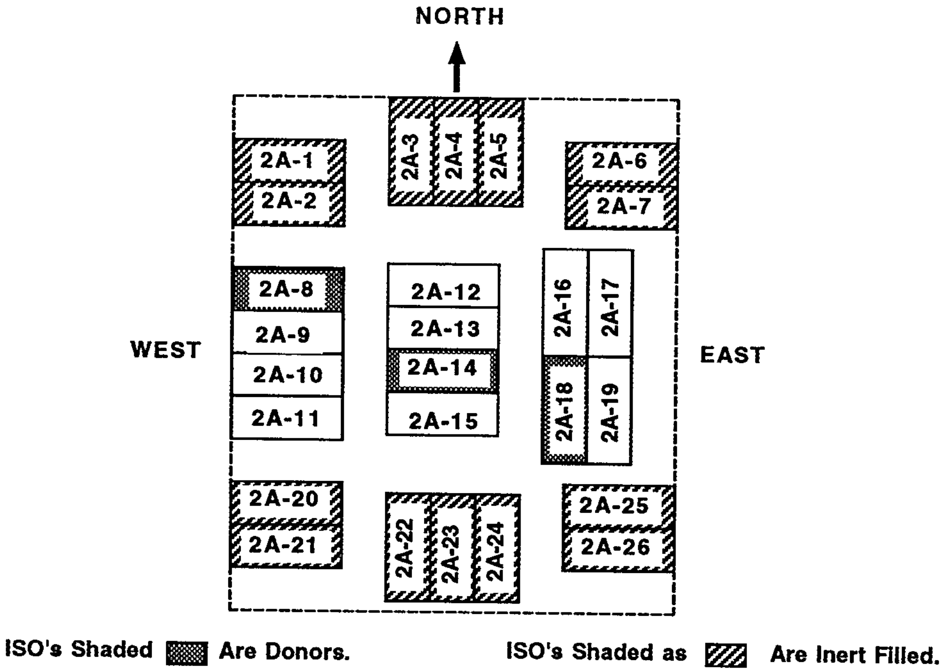

FIGURE 2C. PLAN VIEW OF LEVEL 2, TIER A OF THE TEST CONFIGURATION

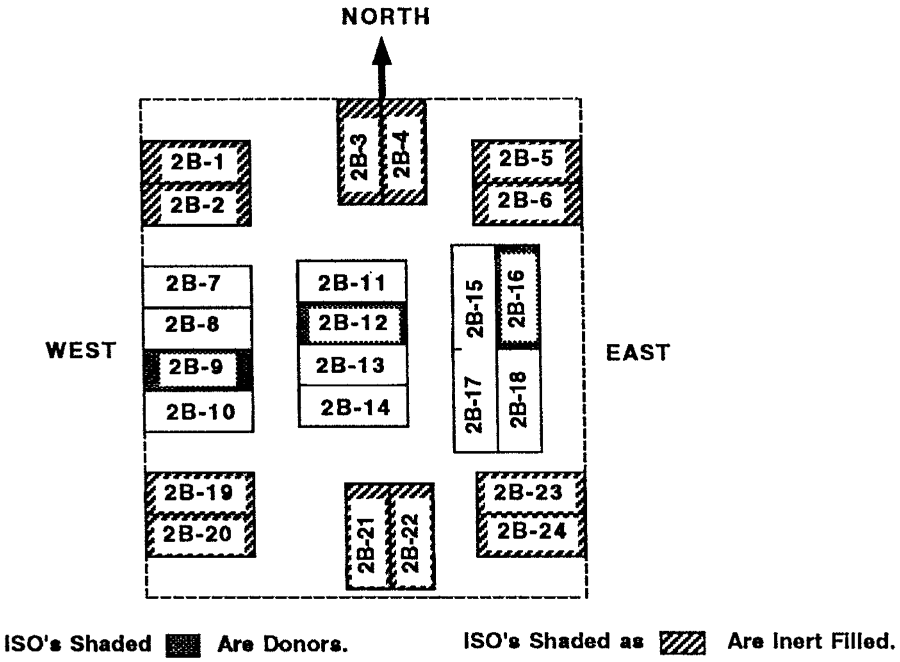

FIGURE 2D. PLAN VIEW OF LEVEL 2, TIER B OF THE TEST CONFIGURATION

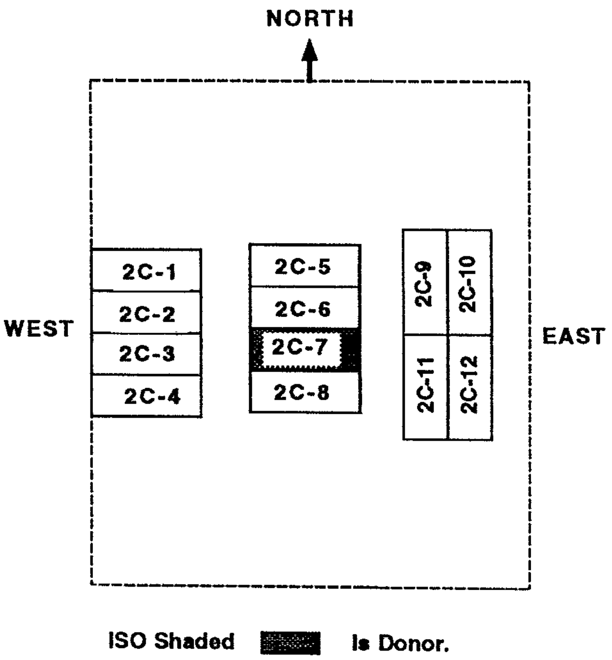

FIGURE 2E. PLAN VIEW OF LEVEL 2, TIER C OF THE TEST CONFIGURATION

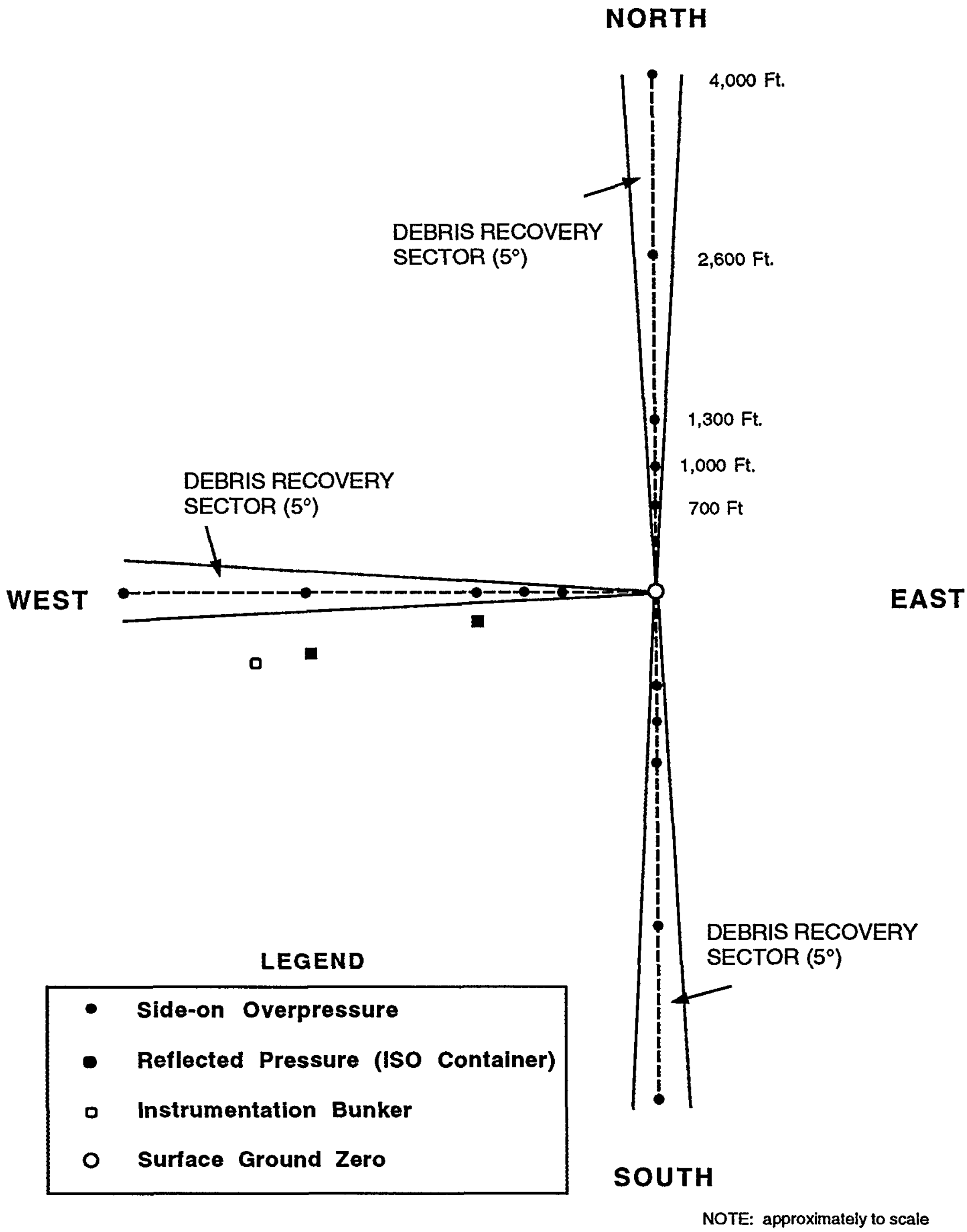

FIGURE 3. MPS ESQD DEBRIS SECTORS AND INSTRUMENTATION LAYOUT

FIGURE 4. MPS AIRBLAST OVERPRESSURE DATA: LEAST SQUARES FIT

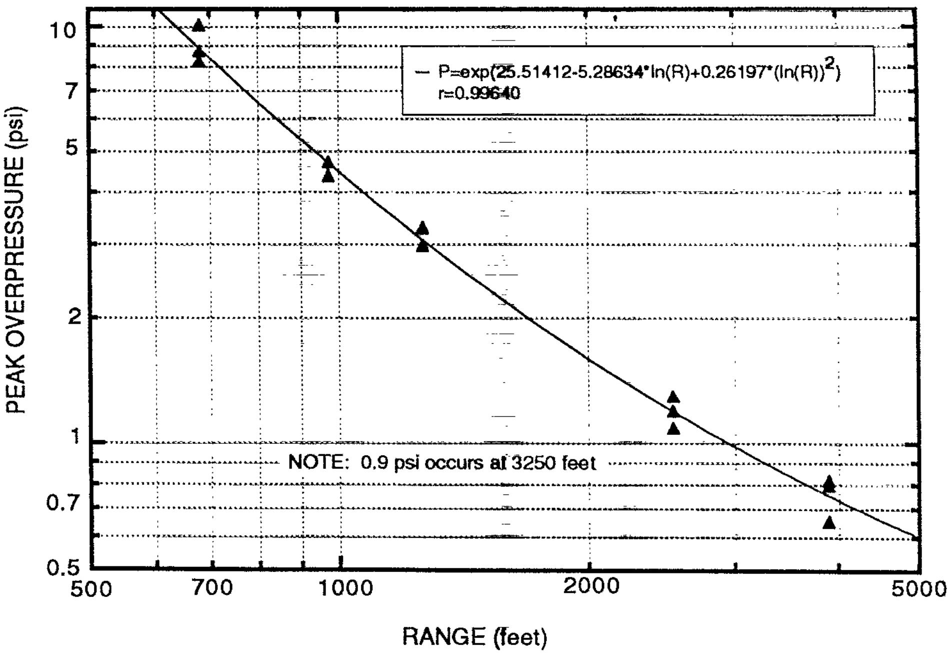

FIGURE 5. MPS POSTIVE IMPULSE DATA: LEAST SQUARES FIT

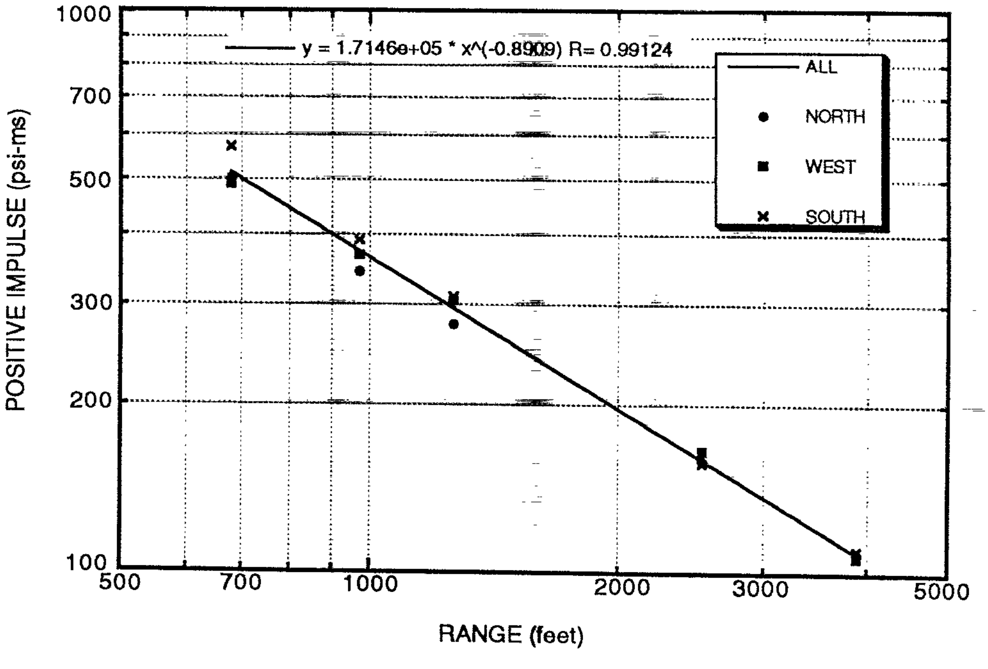

FIGURE 6. COMPARISON OF MPS PRESSURE-DISTANCE DATA WITH KINGERY TNT STANDARD

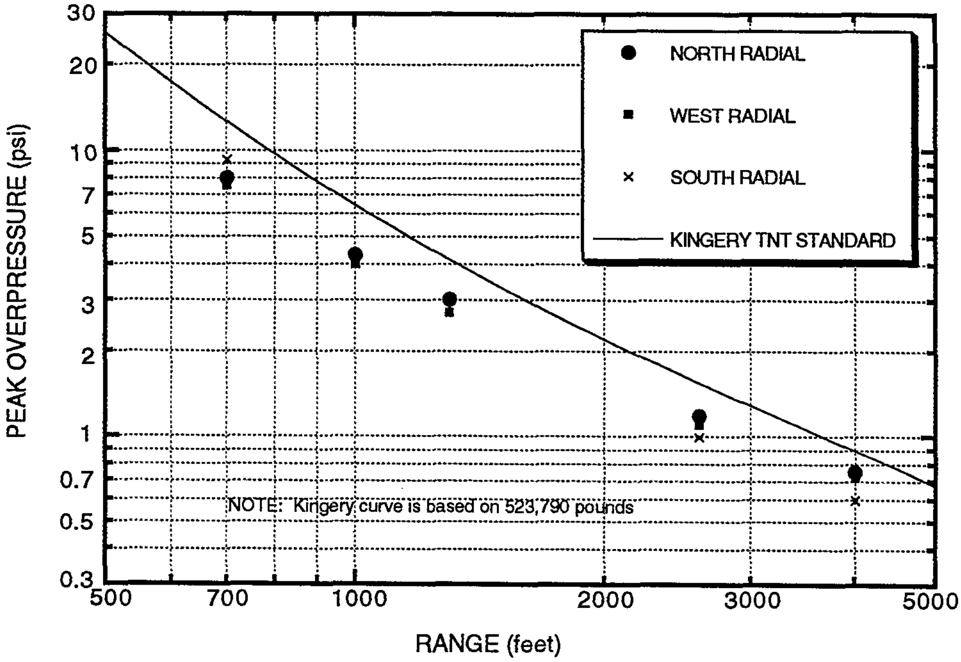

FIGURE 7. MPS IMPULSE-DISTANCE DATA COMPARISON WITH KINGERY TNT STANDARD

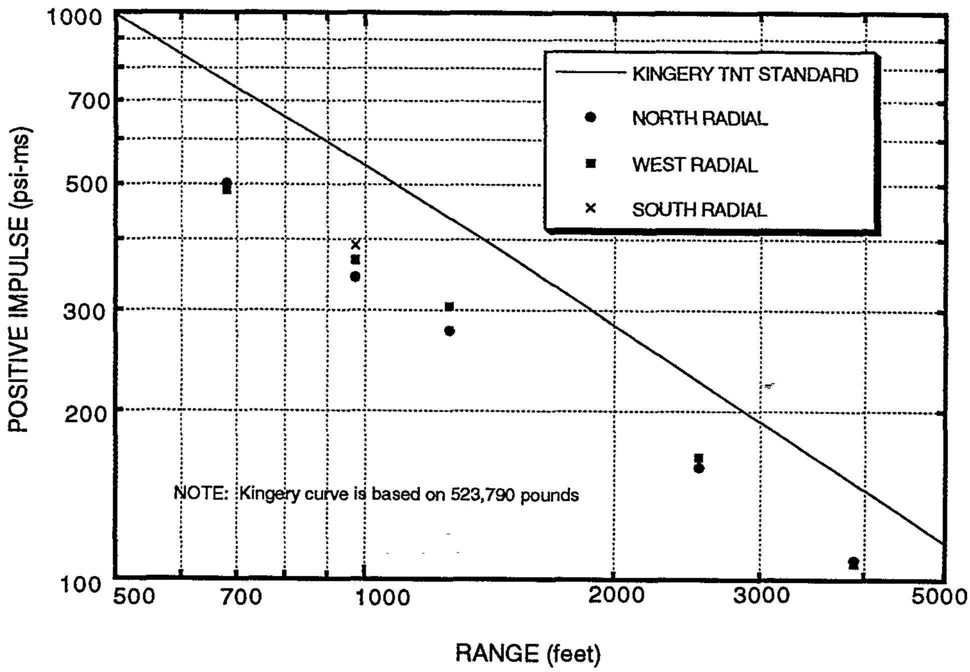

FIGURE 8. MPS EQUIVALENT WEIGHT

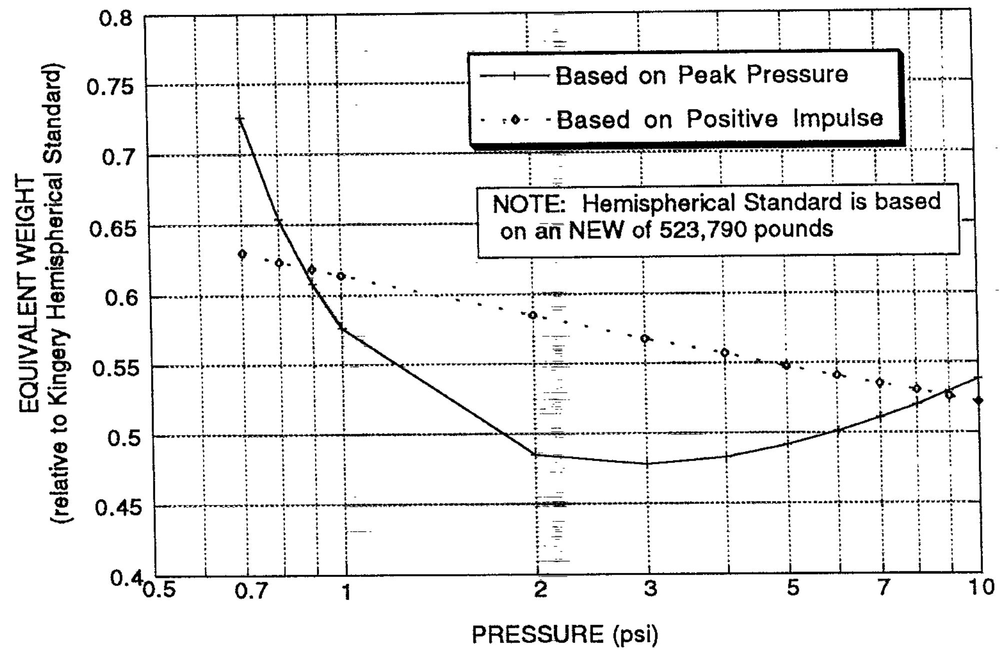

FIGURE 9. MPS DEBRIS RECOVERY

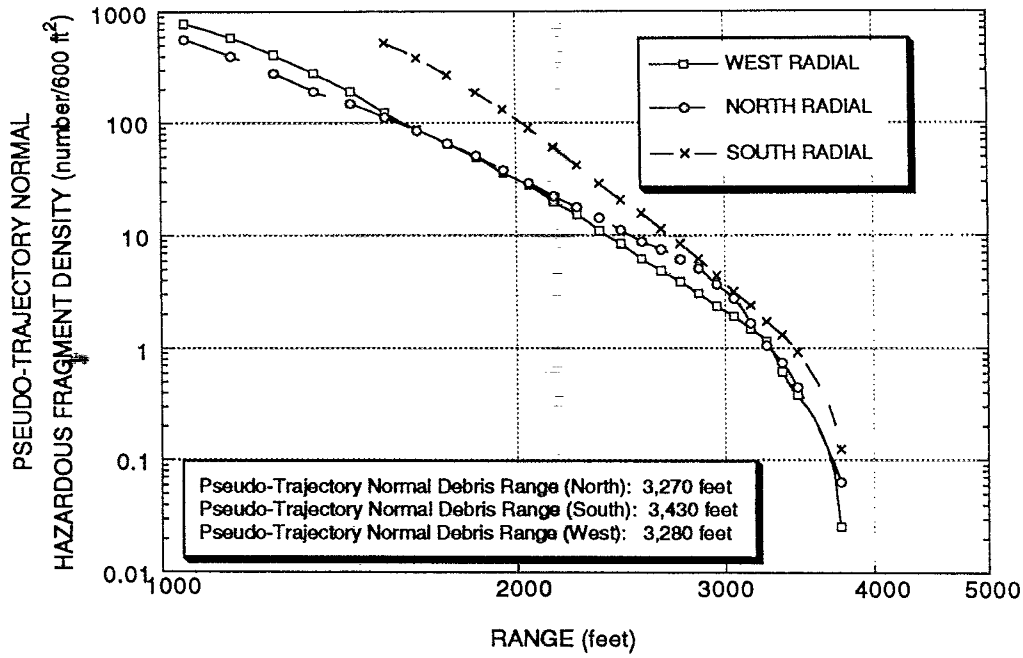

TABLE 1. ESQD RANGES

NEW (pounds)	INHABITED BUILDING DISTANCE (feet)	PUBLIC TRAFFIC ROUTE (feet)
1,000,000	5,000	3,000
1,150,000	5,240	3,145
1,300,000	5,460	3,280

SOURCE: OP-5 (Reference 1)

TABLE 2. RESULTS OF AIRBLAST MEASUREMENTS

RADIAL	HORIZONTAL DISTANCE (feet)	PEAK PRESSURE (psi)	POSITIVE IMPULSE (psi-ms)
North	700.2	8.02	449.62
North	1000.0	4.32	307.48
North	1299.9	3.02	248.01
North	2600.2	1.18	142.14
North	4000.2	0.75	97.18
West	700.2	7.54	438.01
West	1000.0	4.02	329.24
West	1299.9	2.73	272.67
West	2600.2	1.10	147.94
West	4000.2	0.73	95.73
South	700.2	9.24	510.53
South	1000.0	4.00	349.54
South	1299.9	3.00	277.02
South	2600.2	1.00	140.69
South	4000.2	0.60	98.63
West-reflected	1299.9	5.70	Cable Cut
West-reflected	2600.2	2.36	142.14

TABLE 3. DYNAMIC PRESSURE EFFECTS

RANGE	MEASURED SIDE-ON OVERPRESSURE	MEASURED REFLECTED OVERPRESSURE	PREDICTED REFLECTED OVERPRESSURE*	PERCENT DIFFERENCE
(ft)	(psi)	(psi)	(psi)	
1300	2.73	5.70	5.90	-3.4%
2600	1.10	2.36	2.31	2.2%

*prediction based on measured side-on overpressure using Rankine-Hugoniot relationships to predict reflected pressure

NOTE: Reflected impulse also measured--however, finite size of reflecting surface allowed pressure to relieve before total reflected impulse could develop

TABLE 4. DEBRIS RECOVERY DATA--NORTH RADIAL

RLOWER (feet)	RUPPER (feet)	AREA (sq. feet)	155 mm	106 mm	105 mm	4.2"	fuzes	50 cal	fragments	total
1000	1100	9,163		1			3		1,550	1,554
1100	1200	10,036		1			1	1	1,277	1,280
1200	1300	10,908	1				6		1,055	1,062
1300	1400	11,781					5	3	498	506
1400	1500	12,654		2			9	2	476	489
1500	1600	13,526		2			4	4	373	383
1600	1700	14,399					5	1	303	309
1700	1800	15,272		1			1	3	234	239
1800	1900	16,144		1			4	4	222	231
1900	2000	17,017		1			2	1	159	163
2000	2100	17,890					4	2	135	141
2100	2200	18,762					2	2	86	90
2200	2300	19,635					1		75	76
2300	2400	20,508					1		70	71
2400	2500	21,380		2			1		54	57
2500	2600	22,253	1				1		28	30
2600	2700	23,126	1						33	34
2700	2800	23,998					2		27	29
2800	2900	24,871	2				1		41	44
2900	3000	25,744	1				4		22	27
3000	3100	26,616	1				1		35	37
3100	3200	27,489	2						19	21
3200	3300	28,362	1	1					9	11
3300	3400	29,234		1	1				9	11
3400	3500	30,107	1						3	4
3500	4000	163,625	1						13	14
	>4000			2	1				13	16
		TOTAL	12	15	2	0	58	23	6,819	6,929

TABLE 5. DEBRIS RECOVERY DATA--WEST RADIAL

RLOWER (feet)	RUPPER (feet)	AREA (sq. feet)	155 mm	106 mm	105 mm	4.2"	fuzes	50 cal	fragments	total
1000	1100	9,163					2		1,756	1,758
1100	1200	10,036							1,834	1,834
1200	1300	10,908	1				3		1,576	1,580
1300	1400	11,781					5		1,164	1,169
1400	1500	12,654					2		1,002	1,004
1500	1600	13,526	1				2		535	538
1600	1700	14,399					3		439	442
1700	1800	15,272					1		337	338
1800	1900	16,144					1		297	298
1900	2000	17,017					2		188	190
2000	2100	17,890					2		202	204
2100	2200	18,762							124	124
2200	2300	19,635							122	122
2300	2400	20,508							76	76
2400	2500	21,380					2		68	70
2500	2600	22,253							43	43
2600	2700	23,126							33	33
2700	2800	23,998							29	29
2800	2900	24,871	1						24	25
2900	3000	25,744							16	16
3000	3100	26,616							16	16
3100	3200	27,489					2		12	14
3200	3300	28,362		1			1		22	24
3300	3400	29,234					1		10	11
3400	3500	30,107					1		11	12
3500	4000	163,625							7	7
	>4000			1					3	4
		TOTAL	3	2	0	0	30	0	9,946	9,981

TABLE 6. DEBRIS RECOVERY DATA--SOUTH RADIAL

RLOWER (feet)	RUPPER (feet)	AREA (sq. feet)	155 mm	106 mm	105 mm	4.2"	fuzes	50 cal	fragments	total
										*
1000	1100	9,163								*
1100	1200	10,036								*
1200	1300	10,908								*
1300	1400	11,781								*
1400	1500	12,654								*
1500	1600	13,526				1	7		2,624	2,632
1600	1700	14,399	2			3	11		2,355	2,371
1700	1800	15,272		3		2	17		1,761	1,783
1800	1900	16,144	5		4	1	17		1,267	1,294
1900	2000	17,017	2			5	10		1,046	1,063
2000	2100	17,890	1			4	5		780	790
2100	2200	18,762	3		2	3	3		509	520
2200	2300	19,635	3	2	2				385	392
2300	2400	20,508	2			2			244	248
2400	2500	21,380	4			1	2		144	151
2500	2600	22,253			1	1	2		138	142
2600	2700	23,126				1			102	103
2700	2800	23,998	3		1	1			74	79
2800	2900	24,871		1	2				66	69
2900	3000	25,744	5			2			41	48
3000	3100	26,616	1	1	1				28	31
3100	3200	27,489		1	1	2			24	28
3200	3300	28,362			1	2			14	17
3300	3400	29,234	1						17	18
3400	3500	30,107	1		1		1		9	12
3500	4000	163,625	3	2	3				26	34
	>4000		2	2	25	1			13	43
		TOTAL	38	12	44	32	75	0	11,667	11,868

*No recovery in this area

TABLE 7. UNEXPLODED ORDNANCE

TYPE OF ORDNANCE	QUANTITY	NEW (pounds)
155 mm H.E.	2148	33,508
105 mm H.E.	277	1,662
4.2" mortar	791	6,328
106 mm	521	6,773
MK 81 bombs	6	600
Sparrow warhead	38	680
TOTAL		**49,551**

TABLE 8. AIRBLAST ESQD RANGES

NET EXPLOSIVE WEIGHT (pounds)	INHABITED BUILDING DISTANCE (feet)	PUBLIC TRAFFIC ROUTE (feet)
1,000,000	4,032	2,400
1,100,000	4,162	2,480
1,200,000	4,284	2,550
1,300,000	4,400	2,620
1,400,000	4,510	2,690
1,500,000	4,615	2,750

NOTE: TABLE IS BASED ON SCALING RANGES OBTAINED ON MPS TEST FOR 0.9 AND 1.7 PSI. THESE RANGES WERE 3250 FEET (0.9 PSI) AND 1910 FEET (1.7 PSI)

TABLE 9. DEBRIS HAZARD RANGES

FRAGMENT MULTIPLIER	NOTE	DIRECTION		
		NORTH	SOUTH	WEST
1		3270	3430	3280
3	1	3500	3650	3480
27	2	3780	3820	3740

Notes: 1. The number of fragments is proportional to the charge weightratio
multiplier = 1,500,000/500,000=3
2. The number of fragments is proportional to the cube of the charge weight ratio
multiplier = (1,500,000/500,000)^3=27

TABLE 10. MPS ESQD RANGES ADOPTED BY DDESB

NEW (pounds)	INHABITED BUILDING DISTANCE (feet)	PUBLIC TRAFFIC ROUTE DISTANCE (feet)
1,000,000	4,085	2,480
1,100,000	4,220	2,560
1,200,000	4,345	2,640
1,300,000	4,460	2,710
1,400,000	4,570	2,780
1,500,000	4,680	2,840

NOTE: These ranges apply only to the thireeen USMC MPS ships